LWPC Modeling of VLF Perturbations on Overlapping Propagation Paths from Lightning Induced Energetic Electron Precipitation

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Lightning discharges are known to be a source of high amplitude, broad frequency electromagnetic radiation. These electromagnetic waves can cause perturbations in the electron density of the D-region of the ionosphere either by ionization from quasi-electrostatic fields or from induced energetic electron precipitation from the magnetosphere. The effect of these variations is more pronounced at nighttime due to nighttime electron densities being much lower when compared to daytime levels. Because changes in D-region electron density affect the conductivity of the ionosphere, nighttime lightning discharges can perturb the amplitude and phase of VLF communication signals propagating through the Earth-ionosphere waveguide. Most past work in this area has involved unique propagation paths between a transmitter and receiver. Modeling of such perturbation events often involves uncertainty since the perturbed ionospheric profile cannot be uniquely determined. In this work we focus on overlapping VLF propagation paths when signals from two different VLF transmitters share a common path to a receiver. This allows for the geographic area of the overlapping path to be simultaneously diagnosed with two signals with different mode content. Observations show that a lightning induced perturbation on the overlapping path can have a large effect on the amplitude or phase of one signal, while leaving the other wave relatively unaffected. The Long Wave Prediction Capability (LWPC) software package is used to simulate this phenomenon by altering the effective conducting height of the ionosphere near the location of a known nighttime lightning strike. Good agreement is found between the simulation and the observations providing additional constraints on the perturbed ionosphere and a more accurate model of how lightning affects ionospheric electron densities. Analyzing the mode structure of the propagating wave through LWPC simulation has led to a more complete understanding of why ionospheric disturbances often have different effects on individual VLF waves traveling on similar paths.